Journal of Forensic and Legal Medicine 16 (2009) 381–384

Contents lists available at ScienceDirect

Journal of Forensic and Legal Medicine

journal homepage: www.elsevier.com/jflm

Original Communication

ECG-voltage in alcoholics and non-alcoholics with acute alcohol intoxication

Willy Aasebø MD (ECG-voltage in acute alcohol intoxicated patients) *

Medical Department, Rikshospitalet University Hospital, NO-0027 Oslo, Norway

ARTICLE INFO

Article history:
Received 4 July 2008
Received in revised form 26 August 2008
Accepted 15 January 2009
Available online 24 February 2009

Keywords:
Alcohol
Ethanol
Intoxication
ECG
Voltage

ABSTRACT

Alcohol intoxication is probably the most common intoxication worldwide, and may be lethal. The exact mechanism by which ethanol intoxication contributes to death is unknown, although ventricular tachyarrhythmias degenerating into fibrillation is a possible cause. Alcoholics have increased risk of sudden death and, possibly, higher risk than occasional drinkers. In 32 consecutive patients with alcohol intoxication Δ-voltage was the differences in voltage between values at admission (when patients had high blood alcohol levels) and at discharge (when the patients were assumed sober), and was calculated for QRS complexes and T-waves in precordial and bipolar leads. Δ-precordial–QRS-voltage was positive in 13/15 (87%, $p = 0.010$) of the occasional drinkers and in 8/17 (47%, $p = 0.53$) of the alcoholics (alcoholics vs. occasional drinkers: $p = 0.008$). Both Δ-precordial–QRS-voltage and Δ-precordial–T-wave-voltage differed from the group of occasional drinkers to the group of alcoholics, after adjusting for age, sex and s-osmolality. Mean alcohol concentration was 0.29%. Conclusions have to be made with caution. Alcohol in potential lethal blood concentrations seems to increase ECG-voltages in occasional drinkers but not in alcoholics. This indicates that alcohol interferes with the ion channels that create the action potentials of the heart, but in alcoholics an adaptation process has occurred.

1. Introduction

Intoxications with alcohol may be lethal and are probably the most common intoxication worldwide. In a recent study of deaths in police custody 88% of the deaths with undetermined manner of death were related to alcohol (69% of all deaths).[1] In a previous study from Norway 88% of deaths in police custody was related to alcohol, and in 33% of the deaths alcohol intoxication was the only known cause.[2]

The exact mechanism by which ethanol intoxication causes death is unknown. Long-term use of alcohol may cause microscopic fibrosis in the heart muscles (cardiomyopathy)[3] and impaired function of the vagus nerve (vagopathy).[4,5] These changes may contribute to the increased mortality and risk of sudden death that are found in alcoholics.[6,7] Even though alcoholics have higher risk of sudden death than occasional drinkers, arrhythmias may occur directly related to drinking alcohol both in alcoholics and occasional drinkers.[8–10] ECG changes that may increase the risk of arrhythmias have been described in patients with acute alcohol intoxications.[11]

The voltage in a standard surface ECG originates from action potentials created by ion channels in the heart. The measured voltages are influenced by many confounding factors, but changes in voltages in the same subject with and without influence of alcohol might indicate that the function of these ion channels are changed by alcohol. In vitro studies have described changed ion channel function in nerve cells exposed to high concentrations of alcohol.[12]

To my knowledge, no previous studies have measured ECG-voltages in patients with alcohol intoxication. The aims of the present report are, firstly to find out if alcohol affects ECG-voltages in patients with potential lethal blood alcohol concentrations and, secondly, to find out if alcoholics differ from occasional drinkers in their ECG-voltage response to alcohol.

2. Methods

2.1. Subjects and study design

ECGs were taken at admission and before discharge in 32 consecutive patients admitted to Akershus University Hospital for acute alcohol intoxication. Patients that had consumed other toxic alcohols than ethanol, patients presenting with cardiac arrhythmias, AV-blocks or bundle branch blocks, unstable coronary heart disease, heart failure, other severe symptoms that those of alcohol intoxication or patients with daily use of >5 medicines were not considered for inclusion.

Patient characteristics were recorded. Medical treatment, except fluid therapy and vitamins were recorded. The study intended to record medication taken by the patients before they were admitted to hospital. However, the results are not reported because of

* Address: Medical Department, Akershus University Hospital, NO-1478 Lørenskog, Norway. Tel./fax: +47 32070000.
E-mail address: willy.aaseboe@rikshospitalet.no

1752-928X/$ - see front matter © 2009 Elsevier Ltd and Faculty of Forensic and Legal Medicine. All rights reserved.
doi:10.1016/j.jflm.2009.01.016

inaccuracy in these data reported by severely intoxicated subjects. Subjects were classified as alcoholics if they previously had been hospitalized with alcohol intoxications ($n = 16$), if they considered themselves to be alcoholics (admitted daily or periodically uncontrolled consume of alcohol) ($n = 10$), if the had known complications related to long-term use of alcohol ($n = 11$) or if they had been in contact with the alcohol ward ($n = 14$).

2.2. Laboratory examinations and ECGs

At admission for alcohol intoxication serum osmolality (mosm/kg H_2O) was measured to estimate the approximate serum alcohol concentration, in line with the hospital routine at that time. To obtain an estimate of serum alcohol concentration in %, we derived a regression equitation for conversion from a sample of consecutive patients that later were admitted to the hospital and had both serum ethanol and osmolality measured ($n = 62$, adjusted $R^2 = 0.92$): $C_{Ethanol} = (C_{osmolality} - 295)/28$.

The ECGs were recorded on paper with speed 50 mm/s, using a Marquette Electronics Mac 6 marquette or a Sicard 460 Siemens apparatus. 1 mV = 1 mm. Voltages were measured manually, in mm, in three consecutive cycles. For each lead the mean value of these 3 V were used to calculate mean values of the six precordial (V_{1-6}) and the six bipolar leads (I, II, III, avL, avR and avF). The voltages of both QRS complexes and T-waves were included. Finely, Δ-voltages were calculated as the differences between ECG-voltages taken at admission and ECG-voltages taken at discharge.

2.3. Statistical analysis

Δ-voltages were analyzed with one-sided ancova t-tests. Chi squared tests or Pearsons tests were used to compare between alcoholics and occasional drinkers. When Δ values were compared between the group of alcoholics and the group of occasional drinkers the values were adjusted for age, sex and s-osmolality. The adjusted values represent the predicted score for a subject with the average age, sex and s-osmolality using multiple linear regression analysis.

Results are presented with means and SD or SEM. A 5% significance level was chosen using two sided tests. The SPSS (SPSS Inc., Chicago, Illinois) 13.0 or Statview (version 5.0.1) were used for statistical analysis.

3. Results

Alcoholics were older and had higher s-osmolality at admission for acute alcohol intoxication than occasional drinkers (Table 1). The mean time interval between ECGs taken at admission and ECGs taken at discharge was 20 h (range: 6–44). Ten patients (31%) received specific medical treatment (4 N-acetylcystein, 5 carbamazepine, 1 naloxone and flumazenil and 6 miscellaneous neuroleptics).

Table 1
Characteristics of 32 consecutive patients admitted for acute ethanol intoxication. Mean (SD), or number (%).

	Alcoholics ($n = 17$)	Occasional drinkers ($n = 15$)	p
Age (years) (SD)	47.5 (9.9)	29.1 (16.0)	<0.001
Male sex, number (%)	10 (59)	8 (53)	0.60
Patients with comorbidity (%)	6 (35)	5 (33)	0.85
Patients receiving treatment (%)	8 (47)	2 (13)	0.040
S-osmolality (mosm/kg H_2O) (SD)	378 (28)	355 (21)	0.013
Calculated alcohol conc. in (%)	0.34	0.23	
Sodium (mmol/l) (SD)	142.6 (3.8)	144.1 (2.2)	0.19
Potassium (mmol/l) (SD)	4.0 (0.46)	3.9 (0.40)	0.46
Albumin (g/l) (SD)	38.1 (5.9)	42.4 (3.8)	0.08
Calcium (mmol/l) (SD)	2.23 (0.13)	2.25 (0.03)	0.71
Glucose (mmol/l) (SD)	5.8 (1.1)	5.9 (0.8)	0.69

No difference in voltage between values at admission and at discharge (Δ-voltage) was found in the group as a whole. QRS-voltage in the six precordial leads (Δ-precordial–QRS-voltage) was higher at admission that at discharge in the group of occasional drinkers in contrast to the group of alcoholics. Thus, Δ-precordial–QRS-voltage were >0 in 13/15 (87%, $p = 0.010$) of the occasional drinkers and in 8/17 (47%, $p = 0.53$) of the alcoholics (alcoholics vs. occasional drinkers: $p = 0.008$).

Both Δ-precordial–QRS-voltage and Δ-precordial–T-wave-voltage differed between the group of occasional drinkers and the group of alcoholics, after adjusting for age, sex and s-osmolality (Fig. 2). In Fig. 1 an example of a patient with ECGs taken at admission and before discharge is shown.

4. Discussion

The main finding in this study of patients with potential lethal blood alcohol concentrations is the difference in ECG-voltage dynamics between occasional drinkers and alcoholics. Occasional drinkers had higher voltages when the blood alcohol concentration was high (at admission) compared to when the blood alcohol concentration was low or zero (at discharge). Alcoholics, on the other hand, had no differences in voltage in ECGs taken when the subjects were intoxicated compared to ECGs taken when the subjects were assumed sober.

These findings may have two implications. Firstly, that alcohol may interfere with ion channels that create action potentials in the heart. Secondly, that an adaptation process may have taken place in the alcoholics, either directly changing the function of ion channels or that the cardiomyopathy, vagopathy or other chronic conditions related to long term use of alcohol interfere with the voltage response. It is uncertain if these changes in voltage may result in rhythm disturbances.

In vitro studies have described several effects on cell membranes and on ion channels in cerebral tissues caused by alcohol. Alcohol increased the resting polarization over a nerve cell membrane, thereby causing hyperpolarization.[12] Theoretically, this may cause increased inward sodium flux and therefore increased voltage. In addition, in vitro studies on alcohol in high concentrations have described interference with the voltage-dependent sodium channels. The inward sodium flux is a qui process in creating action potentials. In the in vitro studies on nerve cells alcohol generally seem to inhibit the voltage-dependent sodium channel.[12] Several ion channels, involved with action potentials, have been identified in the heart muscle.[13] One recent study found a concentration-dependent inhibitory affect of alcohol on a single cardiac sodium channel.[14] Otherwise, no experimental studies have, to my knowledge, been performed on the effect of alcohol on human cardiac ion channels.

This study has several limitations, some of which are related to the difficulty of obtaining reliable information from intoxicated persons, even the day after a binge. The group of occasional drinkers probably included some patients that were alcoholics or about to become alcoholics. The difference between alcoholics and occasional drinkers in the number that was given medical treatment in hospital may have interfered with the analysis. However t-tests comparing alcoholics that were given treatment with alcoholics without treatment revealed no differences in Δ-voltages (p-values: 0.13–0.57). No toxicology tests were done. Voluntary urine samples could not be collected, and it would have been unethical to install a bladder catheter for this purpose. Another limitation is the small study group. On the other hand it is ethically impossible to

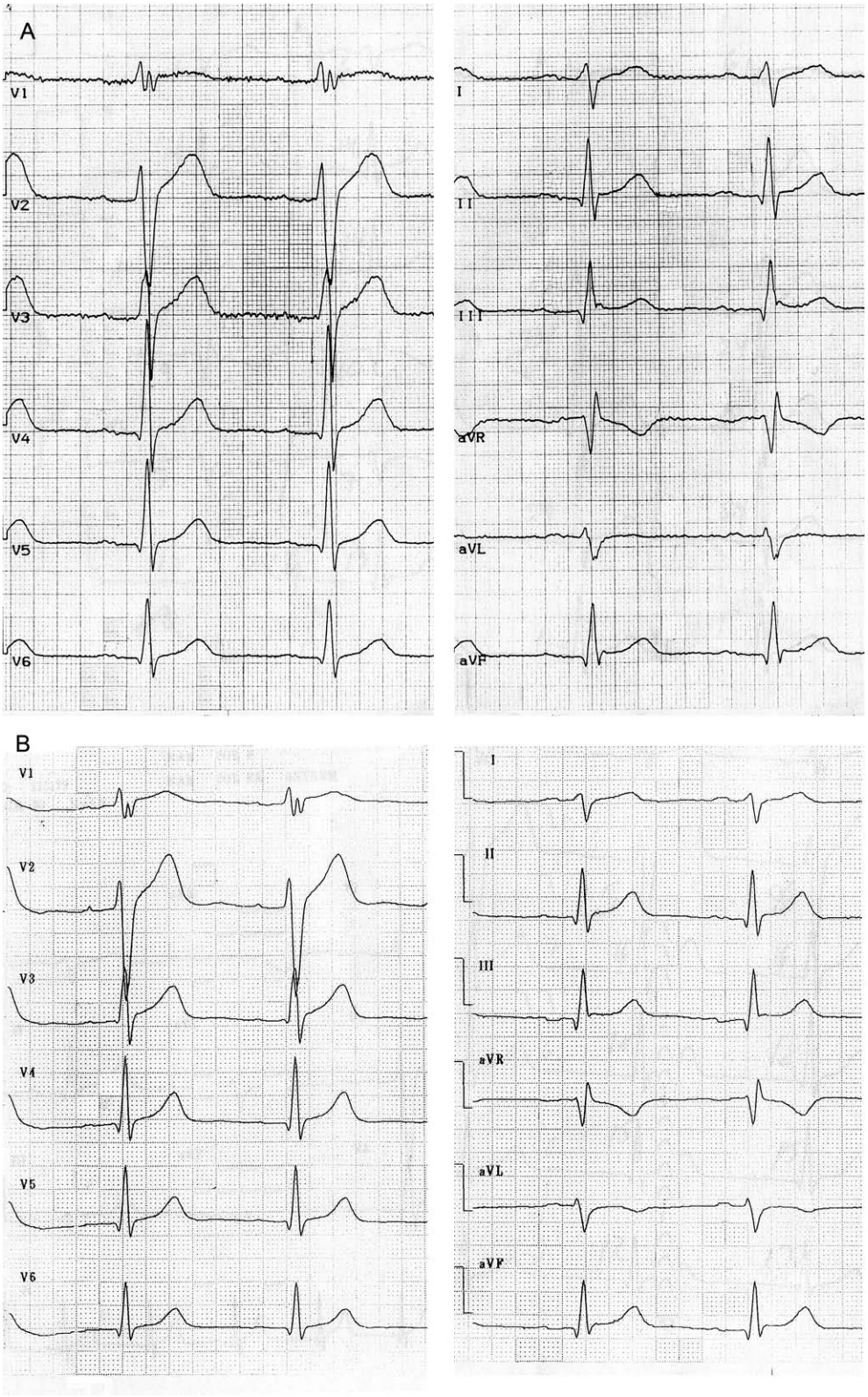

Fig. 1. ECGs taken at admission (A) and before discharge (B) in an occasional drinker with blood alcohol level of 0.37‰. 1 mV = 1 mm. Δ-precordial–QRS-voltage is 5.82 (mm) and Δ-bipolar–QRS-voltage is 2.16 (mm). Δ–T-waves: 0.03 (mm) for the precordial and ÷0.66 (mm) for the bipolar leads.

intoxicate humans to potential lethal blood alcohol concentrations in a laboratory situation. It is therefore necessary to rely on studies with methodological weaknesses in order to investigate the effect of alcohol intoxication in humans.

The ECGs taken before discharge were supposed to be without influence of alcohol. In a few patients all the alcohol was not metabolized at the time of discharge, for example the patient that stayed in hospital only 4 h. Most patients stayed in hospital for a sufficient number of hours to metabolize all, or most of, the ingested alcohol. In addition, the hangover or the abstinence that may occur the day after a serious intoxication is not a normal situation for the subjects, and may also influence on ECGs.

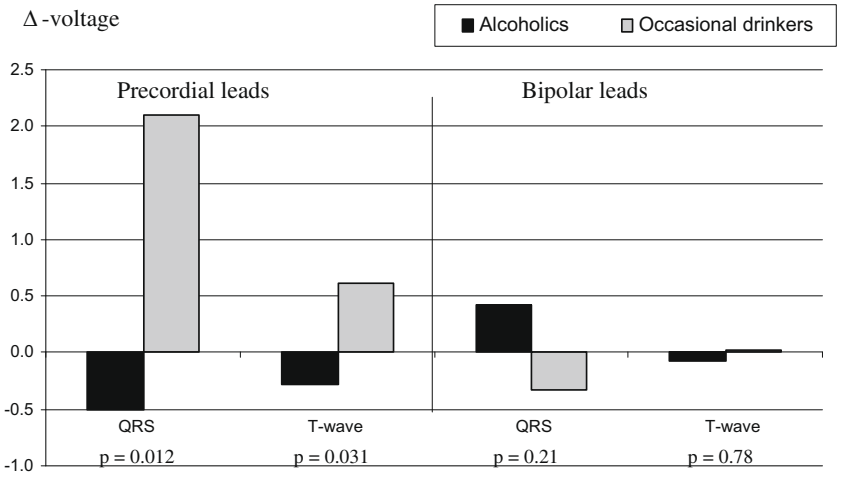

Fig. 2. Differences in voltage between values at admission and at discharge (Δ-values). Positive Δ-value means a higher voltage at admission (when blood alcohol levels were high) than at discharge (when blood alcohol levels were low or zero). Values are adjusted for age, sex and s-osmolality.

Intoxication with alcohol is probably the most common intoxication worldwide. Studies on patients with potential lethal blood alcohol concentrations are seldom published. This study indicates that high blood levels of alcohol interfere with ion channels in the heart. This study also describes interesting differences in ECG-voltage changes between occasional drinkers and alcoholics. These differences may contribute to explain the increased mortality from cardiac arrhythmias that are seen in alcoholics.

Conflict of Interest

There is no conflict of interest in this work.

Funding

There are no funding and no other sources of support top this work.

Ethical approval

The work has been approved by the local ethical committee.

References

1. Southall P, Grant J, Fowler DS, Scott S. Police custody deaths in Maryland, USA: an examination of 45 cases. *J Forensic Legal Med* 2008;**15**:227–30.
2. Aasebø W, Erikssen J, Jonsbu J. Dødsfall i norske politiarrester. *Tidsskr Nor Legeforen* 2003;**123**:1066–7.
3. Askanaa A, Udoshi M, Sadjadi SA. The heart in chronic alcoholism: a non-invasive study. *Am Heart J* 1980;**99**:9–16.
4. Yokohana A, Ishii H, Takaji T. Prolonged QT interval in alcoholic autonomic nervous dysfunction. *Alc Clin Exp Res* 1992;**16**:1090–2.
5. Novak DJ, Viktor M. The vagus and sympathetic nerves in alcoholic polyneuropathy. *Arch Neurol* 1974;**30**:273–83.
6. Lithell H, Aberg H, Selinus I. Alcohol intemperance and sudden death. *BMJ* 1987;**294**:1456–8.
7. Suhonen O, Aroma A, Reunanen A. Alcohol consumption and sudden coronary death in middle-aged Finnish men. *Acta Med Scand* 1987;**221**:335–41.
8. Ettinger PO, Wu CF, De La Cruz C. Arrhythmias and the "holiday heart": alcohol-associated cardiac rhythm disorders. *Am Heart J* 1978;**95**:555–62.
9. Greenspon AJ, Stang JM, Lewis RP. Provocation of ventricular tachycardia after consumption of alcohol. *New Engl J Med* 1979;**30**:1049–50.
10. Thornton JR. Atrial fibrillation in healthy non-alcoholic people after an alcoholic binge. *Lancet* 1984;**2**:1013–4.
11. Aasebo W, Erikssen J, Jonsbu J, et al. ECG changes in patients with acute ethanol intoxication. *Scand Cardiovasc J* 2007;**41**:71–4.
12. Deitrich RA, Dunviddie TV, Harris RA, et al. Mechanism of action of ethanol: initial central nervous system actions. *Pharm Rev* 1989;**41**:489–537.
13. Zipes DD. Genesis of cardiac arrhythmias: electrophysiological considerations. Braunwald cardiology. 5th ed. chapter 20.
14. Klein G, Gardiwal A, Schaefer A. Effect of ethanol on cardiac single sodium channel gating. *Forensic Sci Int* 2007;**171**:131–5.